Build an Interplanetary Scale

By: Catherine Matthews, Dick Fargo, and Jeffrey Craig

Matthews, C., Fargo, D., & Craig, J. (1997). Build An Interplanetary Scale. *Science Scope, 20* (4), 24 – *26.*

Made available courtesy of National Science Teachers Association: http://www.nsta.org/

***** Note: Figures may be missing from this format of the document**

Article:

Help your students understand mass, weight, and gravitational fields with an interplanetary scale. Students can simulate their weight on any planet or satellite with a surface gravitational field equal to or less than Earth's. This includes Earth's moon and all other planets in our solar system except Jupiter, Saturn and Neptune.

In this activity, students use a bathroom scale and a long board to see how their weight changes on other planets and the Moon. Standing on the end of the board with the scale, students see their Earth weight. As the student moves down the board, away from the scale, their weight is redistributed between the two points of support in a proportional manner. When the student stands on the board right above the scale, their Earth weight is shown. At the halfway point on the board, the scale reads one-half of their Earth weight. If they stand at the other end of the board, away from the scale, no weight is supported by the scale, representing zero gravity. Using the gravitational ratios of the planets, computed using each planet's mass and radius, students can calculate where on the board they need to stand to replicate their weight on another planet and the Moon. Divide the weight in pounds by 2.2 pounds per kilogram to get the weight in kilograms.

Understanding mass and weight

Mass and weight are often confused. Mass is a measure of the actual amount of material in a body while weight is a measure of the gravitational force that acts on the material. Weight depends on the object's location. Mass is constant and would be equal on Earth and on the Moon. You weigh six times more on Earth than you do on the Moon because the gravitational force acting on an object on the Moon is one-sixth as strong as the force acting on that same object on the Earth.

Getting down with gravity

The Moon's gravitational force is less than Earth's because gravitational force at the surface of a planet or Moon depends on the mass and radius of the body. If you know the mass and radius of any planet (or the Moon) you can calculate the gravitational ratio, which, in effect, is equal to the ratio of the masses divided by the ratio of the radii squared. Because the number is a ratio in relation to the Earth, the Earth is assigned a standard value of 1.00. For example, to calculate the gravitational ratio of the Moon, students divide the mass of the Moon, 7.36×10^{22} kg, by the mass of the Earth, 5.98×10^{24} kg, to get 0.0124. Then they divide the radius of the Moon by the radius of the Earth to get 0.2732. Finally, they divide 0.0124 by 0.2732^2 to get 0.17, which is approximately one-sixth the gravitational force on Earth.

Similar calculations can show students the gravitational ratios on other planets. Planetary data is also an excellent way for students to practice metric conversions because different references provide data about the planets in different forms. Figure 1 gives one version of the planets' radii in miles. Students will need to convert these numbers to metric before they can compute gravitational ratios. Figure 2 shows how the mass and radius of each planet compares to those measurements of Earth. Students can get a feel for the relative mass and radius of the planets in comparison to Earth. Using these data, students can again compute the gravitational ratio of various planets. For example, Mercury's gravitational ratio as compared to Earth's gravitational ratio equals $0.05/0.382^2 = 0.34$.

Mathematical applications

Teachers can opt to provide students with a table similar to Figure 3. However, asking students to create their own tables gives them practice using ratios and proportions and the metric system, converting between English and metric measurements, and creating and interpreting tables and graphs. Students can also be asked to locate the data needed, such as radius and mass of various bodies, derive their own ratios, complete the remaining calculations, and design a data table.

Additional thoughts

Students may ask, if Jupiter's mass is 318 times that of Earth's mass, and its diameter is over 11 times that of Earth's diameter, and gravity is a function of mass, why is the surface gravity of Jupiter only 2.6 times that of Earth. Encourage students to research that question and try to answer it themselves. If all else fails, the following information might be helpful.

- All mass acts as though it is concentrated at the center of gravity.

- The force of gravity decreases with the inverse square of the distance. For example, if it's twice as far from the center of gravity, then gravity is one-fourth as much.

- Therefore, while Jupiter's gravitational force is certainly greater than Earth's gravitational force, it's not nearly as great as one might think at first glance. This is because although Jupiter's mass is much greater than Earth's mass, Jupiter's mass is spread out over a much larger volume, which decreases Jupiter's surface gravity because of the inverse square law.

This is a simple construction that will provide middle school students with some challenging science and math applications. Elementary school students can use the scale to weigh themselves and "discover" how mass and weight differ and how their weight would change on other celestial bodies.